Riparian Forest, Aquatic Habitat, and Vertebrate Influences on Macroinvertebrate Assemblages in Headwater Streams of Northeast Ohio

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Introduction

It has long been recognized that streams and rivers are integrally tied to terrestrial riparian areas (Minshall 1967). Especially in headwaters, stream biota are dependent on allochthonous inputs from surrounding riparian corridors for nutrients and habitat (Vannote et al. 1980). Headwater streams (typically defined as draining < 13 km^2 watershed area) comprise up to 80% of a watershed's stream network (Meyer et al. 2003). These small streams should be the focus of restoration efforts because of their potential importance for diversity (Vannote et al. 1980) and nutrient processing (Peterson et al. 2001). Historically, many of the headwater streams in the Midwestern United States have received little attention from researchers and land managers. Macroinvertebrates are influenced strongly by microhabitat variables (Sandin and Johnson 2004) and thus have been described as good indicators of local habitat conditions. Studies that examine how multiple taxa interact with each other and are structured by their habitat are lacking for many types of stream systems, particularly in headwaters. Knowledge of factors affecting assemblage structure of biota inhabiting headwater streams is necessary to better guide restoration and management of these ecosystems.

Study Objectives

Determine the composition and structure of macroinvertebrate assemblages in headwater streams of Northeast Ohio

Examine how environmental factors such as riparian forest, aquatic habitat, vertebrates structure these assemblages

Examine the influence of watershed position (upper v. lower) on these relationships

Study Location

This study was conducted in headwater streams of the Cuyahoga Valley National Park, OH, USA, an area of over 13,400 ha comprised of relatively undeveloped land along 35 kilometers of the Cuyahoga River. Much of the Park is characterized by steep, forested ravine systems formed along the multiple tributaries to the Cuyahoga River. The forests are mature second-growth (>70 years old) and composed of mixed-mesophytic species (e.g. *Acer saccharum Marsh*, *Fagus grandifolia Ehrh.*, *Quercus rubra L.*, *Carya ovata (P.Mill)K. Koch*, *Liriodendron tulipifera L.*.). Four perennial streams were selected based on similar riparian forest age (mature second-growth), riparian forest composition and structure (multi-cohort stand of native species), geomorphic landforms (presence of floodplains and terraces), stream gradient (1-5%) and substrate (minimal siltation).

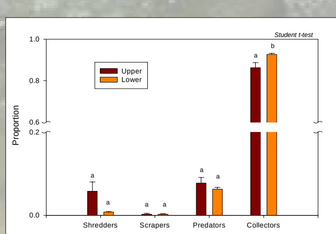
To examine variation in the structure of macroinvertebrate assemblages across watershed position, upper and lower reaches of each stream were sampled in the summer of 2004, for a total of four upper (1st or 2nd stream order) and four lower (2nd or 3rd stream order) reaches. Each 100 m reach was randomly selected and sampled for benthic macroinvertebrates, riparian forest, aquatic habitat, and vertebrate fishes and salamanders.

Macroinvertebrates

Each reach was sub-divided into three segments (approximately 33.33 m each) and sampled for macroinvertebrates. A surber sampler was placed in flowing water and substrate was sifted within a 0.25 m square area for three to five minutes. Riffles, runs, pools, and margins of the stream within each reach segment were jabbed with the D-frame kicknet for five minutes. The samples were preserved in the field. In the lab, samples were sorted and identified.

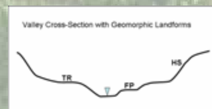
	Watershed Position	
Mean Diversity Indices	Upper	Lower
Richness (S)	21 (1.83)	24 (1.87)
Evenness	0.43 (0.05)	0.45 (0.08)
Shannon Diversity (H')	1.3 (0.14)	1.44 (0.28)

Twelve orders, forty-five families, and 12,691 individuals were collected and identified. Each family was categorized into one of four functional feeding guilds: Collectors (collector-gatherers and collector-filterers), Predators (engulfers and piercers), Scrapers (scrapers and grazers), or Shredders.

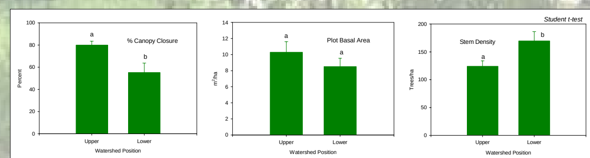


Riparian Forest

Transects were established perpendicular to stream-flow across the stream valley at 33, 66, and 100 m within each reach. For each transect, circular plots (400m^2) were centered on riparian geomorphic landforms (e.g. floodplain, terrace, valley toe-slope) and all tree stems greater than 10 cm DBH (diameter at breast height= 1.35 m) were identified and measured. Using a concave spherical densiometer, riparian canopy cover was estimated from the center of the stream for each reach segment and averaged for the stream reach.

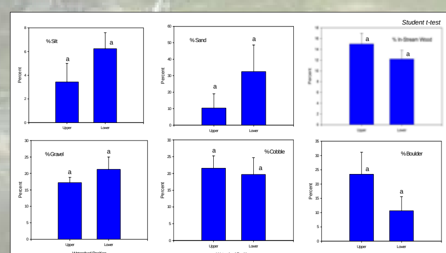


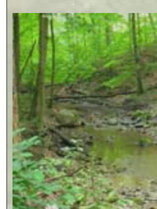
	Watershed Position	
Mean Diversity Indices	Upper	Lower
Richness (S)	3.1 (0.26)	3.5 (0.28)
Evenness	0.76 (0.07)	0.79 (0.05)
Shannon Diversity (H')	0.95 (0.10)	1.00 (0.53)



Aquatic Habitat

At the end of each reach segment (0, 33, 66, and 100 m), substrate type (percent sand, silt, gravel, cobble, and boulder) was estimated visually within a 1 m wide area of stream channel bottom, and averaged for the entire stream reach. Large wood habitat was estimated visually for each segment and averaged for the entire stream reach.

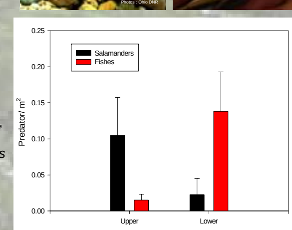




Vertebrates

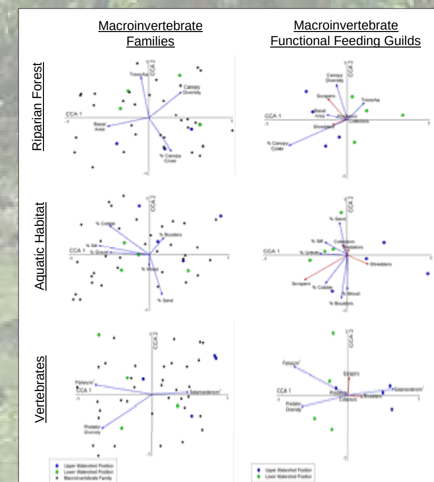
Fish were sampled with single-pass electrofishing using a backpack unit (Smith Root, Inc. Model LR-24 Electrofisher), encompassing the entire 100 m site. The fish were preserved in the field and taken to the lab to be identified and measured. Salamanders were sampled within a randomly selected 30 m section of each stream reach by turning over rocks and sifting leaf packs within the stream and the adjacent stream bank. Sampling took place for a minimum of 30 minutes. Salamanders were identified to species and released at the site of capture. Only salamander species with aquatic larval life-stages were recorded as potential vertebrate predators.

Fish were present in all downstream reaches and one upstream. Thirteen fish species were collected, however two species were most abundant and present at all reaches with fish, *Rhinichthys atratulus* and *Semotilus atromaculatus*. Salamanders were present in all upstream and 3 downstream reaches. Two salamander species with aquatic larval stages were collected, *Desmognathus fuscus fuscus* and *Eurycea bislineatea*.

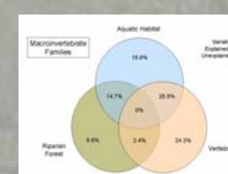


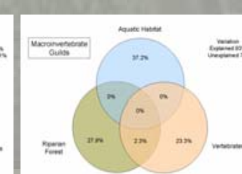
Species- Environment Relationships

We used canonical correspondence analysis (CCA), to examine the relationships between relative abundance of macroinvertebrate families and functional feeding guilds and environmental factors. CCA is comparable to multiple regression, where "species" are dependent variables and constrained by measured environmental factors, which serve as independent variables. Three separate CCAs were conducted for families and feeding guilds, one for each group of environmental factors: riparian forest, aquatic habitat, and vertebrates. Vectors represent strength and direction of relationships between species and environmental factors.



To further partition the variance in the macroinvertebrate species that is explained by environmental factors, partial canonical correspondence analysis was run for families and guilds. For families, an interaction between aquatic habitat and vertebrate predators is the primary factor explaining 25.5% of the variation for the assemblages. For feeding guilds, aquatic habitat is the primary factor explaining 37.2%.





Conclusions

In headwaters streams of Northeast Ohio, macroinvertebrate assemblages are more diverse in downstream reaches and collector species are the dominant guild across watershed position. Assemblage composition (families) are primarily regulated by vertebrates and aquatic habitat, explaining over 66% of the variation. Assemblage structure (functional feeding guilds) is primarily regulated by aquatic habitat, but riparian forest and verterates also explain large amounts of variation.

For restoration and management, aquatic habitat quality is the most important environmental factor to promote healthy and diverse macroinvertebrate assemblages. However, the connection between riparian areas and streams is evident and pivotal. For example, large wood is considered aquatic habitat, but riparian forests are the source. Additional research on these connections between riparian and stream areas is needed. The two are not succinct ecosystems, but each influences the other and research needs to be collaborative so that common patterns can be revealed.

Salaries and funding were provided by the Ohio Agricultural Research and Development Center (OARDC) SEEDS Program, the Ohio Sea Grant Program, the School of Environment and Natural Resources, The Ohio State University, and the USDI National Park Service.

References

Meyers, J.L., L.A. Kaplan, D. Newbold, D.L. Strayer, C.J. Woltemade, J.B. Zedler, R. Beilfuss, Q. Carpenter, R. Semlitsch, M.C. Watzin, P.H. Zedler. 2003. Where rivers are born: the scientific imperative for defending small streams and wetlands. American Rivers and Sierra Club.

Minshall, G.W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48:139-149.

Peterson, B.J., W.M. Wollheim, P.J. Mullolland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Marti, W.B. Bowden, H.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S. Gregory, and D.D. Morrell. 2001. Control of nitrogen export from watersheds by headwater streams. Science 292:86-89.

Sandin, L. and R.K. Johnson. 2004. Local, landscape and regional factors structuring benthic macroinvertebrate assemblages in Swedish streams. Landscape Ecology 19:501-514.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing.1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37:130-137.